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Jacobsen, Lærke Bang; Johannsen, Bjørn Friis; Rump, Camilla Østerberg; Jensen, Jens Højgaard

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DIDACTICAL CONTRACT: AN ANALYTICAL CONCEPT TO FACILITATE SUCCESSFUL IMPLEMENTATION OF OPEN-ENDED PHYSICS LABS^{*})

Lærke Bang Jacobsen¹, Bjørn Friis Johannsen²,
Camilla Østerberg Rump² & Jens Højgaard Jensen¹

¹Roskilde University, ²University of Copenhagen

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What seems straightforward on paper might turn out to be complex in reality. This is a lesson often learned by educational designers when implementing variations of open-ended alternatives to traditional education and disappointedly reviewing the outcome. Based on observations of discouraging outcomes of alternative laboratory work in secondary and tertiary physics education we decided to approach the underlying cause of the problem. Framed in the theory of Didactical Situations in mathematics we adapt the concept of the didactical contract to the physics education context to locate aspects of the traditional laboratory learning environment that would lead to resistance from those involved if faced with alternatives. We conclude that in the traditional laboratory context both teachers and students lean heavily on a type of algorithm that ensures an appearance of having successfully completed the assigned tasks. We find evidence that this algorithmic didactical contract permeates through secondary education into university physics education. Our results allow for a better renegotiation of didactical contracts and thus for avoiding typical problems related to the implementation of alternative tasks. One might expect physics students to be special in their explicit interest in physics and thus plan educational activities accordingly. Based on our results, however, we find this an ill-advised strategy.

BACKGROUND, FRAMEWORK AND PURPOSE

Laboratory work in physics education (labwork), both at upper secondary education (labwork2) and introductory tertiary (labwork3) levels, continues to be a strongly teacher-guided activity. Alternatives to the guided labwork emphasises inquiry-based, student-centred authentic tasks. When properly implemented, such shifts have been shown to better spur student motivation as well as substantially enhance learning outcomes (DeHaan 2008). However, when introducing alternative labworks, teachers and educational designers are often experiencing considerable resistance from both students and faculty involved; resistance expressed in student and teacher frustration, resignation, disappointment etc. This resistance, as well as suggestions for resolution, is plentifully reported. At the MIT Physics Department problems concerning the implementation of Technology Enhanced Active Learning in a university electromagnetism lab was ascribed to insufficient training of both students and teaching staff. In Australia a solution was found in supporting labwork2 students

gradually coming to understand the purpose in terms of intended learning outcomes (Hart et al. 2000).

Having observed alternative physics labworks at both secondary and university level and experienced student failure at both levels, comparisons of a posteriori analyses lead us to conclude that although student/teacher reactions to the attempts were diverse they also had one significant communality that could explain the disappointing outcomes: the alternative labworks introduced conflicts of expectations regarding learning outcomes, fostered by traditional labwork praxis.

The observed labwork2 environment required of the students to approach their own video-recordings of sporting activities from a physics perspective. The students enthusiastically took on the task, but the challenge of turning sports into physics resulted in frustrations instead of the intended engaged physics-exploration.

Given a box containing an assortment of springs and weights, students in the labwork3 setting were asked to utilize their physics knowledge to construct a time-measurer. Disappointedly teachers observed that some students felt satisfied using their watches to time their oscillating contraption. Teachers had expected the students to be ‘different’ from upper secondary students in that all would engage in using physics in an authentic context. Instead teachers saw that some students treated the task as a banal problem aimed at a quick resolution.

Rather than approaching these problems by remedying the context-specific problems (as was done at e.g. MIT), we have decided to focus our inquiry at gaining a deeper understanding of that which underlies the apparently conflicting expectations fostered by traditional labwork praxis. Inspired by the French Theory of Didactical Situations in Mathematics (TDS) we frame such aspects of expectations towards learning outcomes within the metaphorical notion of the didactical contract:

The didactical contract is the rule of the game and the strategy of the didactical situation. It is the justification that the teacher has for presenting the situation, [...] a relationship [...] which determines – explicitly to some extent, but mainly implicitly – what each partner, the teacher and the student, will [...] be responsible to the other person for. This system of reciprocal obligation [and expectation, we argue] resembles a contract. (Brousseau 1997, p.31)

Thus, by applying a theoretical construct to a novel context, the purpose here is to offer important input to assisting the implementation of alternatives to traditional teacher-guided labwork at both secondary and tertiary level education.

RATIONALE

We focus our attention on problems of the traditional labwork praxis relevant to informing and appreciating what is at stake when replacing traditional physics labwork with alternatives.

The time-measurer task was introduced as the first labwork³ of the introductory physics course leading us to suspect that new physics students carry with them preformed ideas about how physics is taught at the university level, ideas developed in upper secondary school, expressed through the didactical contract signed in traditional labwork² settings. Such ideas are influencing factors in the conflict of expectations related to the alternative labworks.

The research question is two-fold: (A) What aspects of the didactical contract formed between teachers and students when doing traditional guided physics labwork in secondary education give rise to a breach of contract when alternative labworks are introduced; (B) what preformed ideas about the teaching and learning in university physics labwork do new university students hold that could originate in such aspects?

METHOD

It is necessary to unfold the concept of the didactical contract to characterise relevant aspects of the traditional labwork didactical contract formed between teachers and students. Corresponding to the different status of the contract at micro- (concerning intra-exercise issues), meso- (con. exercise realisations) and macro-level (con. teaching objectives) Hersant and Perrin-Glorian (2005) have developed a concept of the didactical contract as four intertwined dimensions. These dimensions, adapted to the physics labwork setting, consist of: (1) the physics domain of knowledge (macro-level); (2) the didactical status of the knowledge (meso-level); (3) the nature and characteristics of the ongoing didactical situations (meso-level); and (4) the distribution of responsibility between teacher and student with respect to the knowledge at stake (micro-level).

The empirical basis, a purposeful spread of research-interaction (curriculum and task analysis, outcomes validation, observation, and interviews) with actors in secondary physics education, was analysed according to the dimensions of the didactical contracts. The first dimension was informed through task-analyses focusing on what conceptual, procedural and epistemological aspects students would hypothetically need to master, in order to independently complete the prescribed labwork². The analysis of the second dimension was informed through curriculum analysis and teachers' reflections. The third dimension was informed by analysing observations, along with analyses of lab-reports authored by students and post-lab student interviews. Finally the distribution of responsibility was extracted by interaction-analyses of labwork² video-recordings and teacher and student interviews. To inform our understanding of the macro- and meso-contract at introductory tertiary level 26 interviews were performed with new physics students at a traditional European research university, focusing on their perceived expectations of learning-activities to come. Three student pairs as well as one teacher were subsequently observed and interviewed in-action during one session of labwork³ at the end of their first semester.

RESULTS

To characterise the relevant aspects of the didactical contract established in the tradition of guided laboratory works at both secondary and tertiary level, the data were analysed according to the scheme of dimensions (and the underlying levels) of the didactical contract, as described above.

The analysis of the data according to the first dimension revealed a complexity of demands for even simple practical works. At the apparent level of the curriculum students have to e.g. operate in and between the material world and the world of theories and models along with possessing operational abilities related to the multitudes of representations presented in labwork2.

The second dimension analysis revealed a mesh of purposes in play for educational labwork, for example expressed by teachers as confusion about the didactical status of labwork2 activities.

Observation of labworks and subsequent analysis informed the third dimension, revealing information of how students and teachers perceived the task-elements. Opposed to what was expected from the first dimension task-analyses students did not have to explicitly address the complex web of task and subtasks. Instead they were guided through the task by following a pre-rehearsed algorithm for performing laboratory work.

Regarding the fourth dimension, analysis concluded the distribution of responsibility as 'smooth'; students and teacher felt secure of their roles and responsibilities.

Together the four dimensions lead us to the concept of an algorithmic didactical contract that renders labwork a mere rehearsal of an algorithm. If properly complied with, this algorithm facilitates curriculum content in a way that to both students and teacher have come to appear a sound and satisfactory engagement with physics content. Since the algorithm guarantees an outcome in moving away focus from the process this aspect of the contract results in a breach when alternative labworks are introduced.

Analysis of interviews with new physics students verified that students carry with them the notion that it is legitimate to approach aspects of learning physics in an algorithmic fashion. In observing and interviewing students in action half a year after commencement we ascertained this attitude towards learning in the lab - apparently originating in the algorithmic didactical contract.

CONCLUSIONS AND IMPLICATIONS

Two conclusive characteristics of the didactical contract, each answering the two parts of the research question are highlighted: (A) The didactical contract setting of labwork2 dictates an algorithmic approach to labwork and (B) the contract is so well established that it permeates through secondary education to the tertiary education level. This result will have implications for those teachers and educators who take

into account the necessity of renegotiating the didactical contract when implementing alternative labworks.

Further the pattern of contradictions between dimensions (1 contradicting 3; 2 contradicting 4) needs attention. It appears to be an indication of a hierarchical relationship across the micro- to macro-levels which, if understood, could have implications for our approach to educational change.

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